THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

June 03, 2003

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: *60/388,320*
FILING DATE: *June 14, 2002*

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

P. SWAIN
Certifying Officer

06/14/02 J1129 U.S. PTO

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
REQUEST FOR FILING PROVISIONAL PATENT APPLICATION

A / Pm

Under 35 USC 111(b)

(Not for DESIGN cases)

Box:
PROVISIONAL
APPLICATION

jc879 U.S. PTO 60/388320

Hon. Commissioner of Patents
Washington, D.C. 20231

PROVISIONAL APPLICATION
Under Rule 53(c)

Sir:

Herewith is a PROVISIONAL APPLICATION
Title: CELLULAR BASE STATION AUGMENTATION SYSTEMS AND METHODS

Atty. Dkt. PW 0274076 (**M#**) | P018-US PROV (**Client Ref**)

including:

Date: June 14, 2002

1. Specification: 13 pages 2. ☐ Specification in non-English language 3. ☒ Drawings: 15 sheet(s)
4. The invention ☐ was ☒ was not made by, or under a contract with, an agency of the U.S. Government.
   If yes, Government agency/contact # =
5. ☐ Attached is an assignment and cover sheet. Please return the recorded assignment to the undersigned.
6. Small Entity Status ⌀ ☐ is Not claimed ☒ is claimed (pre-filing confirmation required)
   NOTE: Do NOT File IDS!
7. ☐ Attached:
8. This application is made by the following named inventor(s) **(Double check instructions for accuracy.):**

(1) Inventor	Gideon		ARGAMAN
	First	Middle Initial	Family Name
Residence	Yoqne'am	Israel	Israel
	City	State/Foreign Country	Country of Citizenship
(2) Inventor	Paul		LEMSON
	First	Middle Initial	Family Name
Residence	Woodinville	WA	USA
	City	State/Foreign Country	Country of Citizenship
(3) Inventor	Shmuel		MILLER
	First	Middle Initial	Family Name
Residence	Yoqne'am	Israel	Israel
	City	State/Foreign Country	Country of Citizenship
(4) Inventor	Joseph		SHAPIRA
	First	Middle Initial	Family Name
Residence	Haifa	Israel	Israel
	City	State/Foreign Country	Country of Citizenship
(5) Inventor			
	First	Middle Initial	Family Name
Residence			
	City	State/Foreign Country	Country of Citizenship

9. NOTE: FOR ADDITIONAL INVENTORS, check box ☐ and attach sheet (PAT102A) with same information regarding additional inventors.

	Large/Small Entity		Fee Code
10. Filing Fee	$160/$80	+80	114/214
11. If "assignment" box 5 is X'd, add recording fee.	$40	+0	581
12.	TOTAL FEE =	$80	

13. **Address communications to the correspondence address associated with our Customer No.**

00909

PLEASE CHARGE OUR DEP. ACCT.

Our Deposit Account No. 03-3975

Our Order No. 081746 (C#) | 0274076 (M#)

CHARGE STATEMENT: The Commissioner is hereby authorized to charge any fee specifically authorized hereafter, or any missing or insufficient fee(s) filed, or asserted to be filed or which should have been filed herewith or concerning any paper filed hereafter, and which may be required under Rules 16-17 (missing or insufficient fee only) now or hereafter relative to this application or credit any overpayment, to our Account/Order Nos. shown in the heading hereof for which purpose a duplicate copy of this sheet is attached.

Pillsbury Winthrop LLP
Intellectual Property Group
By Atty: for Anthony L. Miele Reg. No. 34393

Sig: Thomas P. Hilliard Fax: (703) 905-2500
Reg. No. 40330 Tel: (703) 905-2146

Atty/Sec: ALM/sdm

NOTE: File in duplicate with 2 post card receipts (PAT-103) & attachments

APPLICATION UNDER UNITED STATES PATENT LAWS

Atty. Dkt. No. PW 274076
(M#)

Invention: CELLULAR BASE STATION AUGMENTATION SYSTEMS AND METHODS

Inventor (s): ARGAMAN, Gideon
LEMSON, Paul
MILLER, Shmuel
SHAPIRA, Joseph

For Correspondence Address
00909
Pillsbury Winthrop LLP

This is a:

☒ Provisional Application

☐ Regular Utility Application

☐ Continuing Application
☒ The contents of the parent are incorporated by reference

☐ PCT National Phase Application

☐ Design Application

☐ Reissue Application

☐ Plant Application

☐ Substitute Specification
Sub. Spec Filed ________
in App. No. ___/________

☐ Marked up Specification re
Sub. Spec. filed ________
In App. No ___/________

SPECIFICATION

CELLULAR BASE STATION AUGMENTATION SYSTEMS AND METHODS

Field of the Invention
The present invention relates to systems and methods for augmenting the functionality of existing cellular base station systems.

Description of Background Information
Some existing cellular base stations have the capability for transmission of multiple air interfaces (radio transmission signal formats used in wireless multiple access networks). Examples of such air interfaces, defined in cellular industry standards, include AMPS (analog FM employing a 30 kHz channel – Advanced Mobile Phone System), CDPD (cellular digital packet data employing a 30 kHz channel), and CDMA (code division multiple access employing a 1.25 MHz channel).

One approach known in the art for simultaneous transmission of multiple air interface signals employs low-power combining at baseband frequencies, Intermediate Frequencies (IF) or Radio Frequencies (RF). In such a case, and where significant RF transmit power is required, a multicarrier linear power amplifier (MCPA) may be employed. A composite low-power signal consisting of multiple signal components representing various air interfaces is amplified by the MCPA, then filtered appropriately and radiated by the base station antenna.

Many cellular base stations have the capability to simultaneously receive of multiple air interface signals. Also, a cellular base station is typically capable of receiving and demodulating multiple signals of a single air interface type.

Advanced cellular base stations typically employ a receive diversity capability, which employs two separate antennas or two separate sets of antenna elements for reception of radio signals from mobile or fixed subscriber units. An example of such an advanced cellular base station is that employed in cellular CDMA networks.

Existing cellular base stations could benefit materially (in terms of Forward [base station to mobile] link performance) from the addition of a capability known as transmit diversity, which employs two separate antennas or two separate sets of antenna elements for transmission of base station signals to mobile or fixed subscriber units. Transmit diversity base stations employ signal processing means (typically implemented with a suitable transform) to operate on a first transmission signal to be radiated from a first or Main transmit antenna, thereby obtaining a second or Diversity transmission signal to be radiated from a second or Diversity transmit antenna. In order to benefit from the transmit diversity capability, mobile or fixed subscriber units must have a capability to appropriately process the two separate Forward Link signals and obtain a net performance benefit, under certain conditions e.g., slow-moving or stationary subscriber units.

It is customary that each base station location, known as a Cell Site, is equipped for multiple separate coverage zones or Sectors, where each sector covers a certain azimuthal range. A typical Cell Site may host 3 sectors. In such a case, 3 separate sets of directional antennas provide coverage.

In a case where a Receive diversity capability is provided for each Sector, two receive antennas per sector or two sets of receive antenna elements per sector are provided. When it is desired to

add a capability for Transmit diversity for each Sector, two transmit antennas per sector or two sets of transmit antenna elements per sector are provided. If the use of two separate transmit antennas and two separate receive antennas per Sector were contemplated, in certain urban or suburban applications there are zoning or other regulatory restrictions which prevent deployment of more than a certain quantity of antennas per cell site, or alternatively a maximum overall size of the electromagnetic radiating structure may be specified by local ordinances.

In a case where local ordinances permit the deployment of only one radiating structure or one radome-covered structure per Sector, it is necessary to employ innovative approaches to obtain the desired radio system performance while simultaneously complying with local ordinances. One such approach known in the art is to employ a single antenna for both transmit and receive along with a suitable filter network known as a Duplexer. The Duplexer feeds signals from the transmit and receive sections of a base station to a single antenna. In the event that Diversity transmit and receive capabilities are needed, a second antenna fed by a Duplexer may be used, or alternatively an antenna with two sets of dual-slant cross-polarized antenna elements within a single radome may be employed. In that case, the +45 degree elements may be used for the first or Main transmit and receive functions while the –45 degree elements may be used for the second or Diversity transmit and receive functions.

Summary of the Invention

The present invention is provided to improve wireless communications systems. Certain aspects of the present invention are intended for base station augmentation, and minimize the need for modifications to existing radio base stations in order to provide additional highly-desirable new features, including transmit diversity.

The present invention is directed to a system or method, or one or more components thereof. In accordance with such a system or method, an existing and operational base station serving a given cell or sector has a main antenna and a diversity antenna. The existing antennas typically continue to be employed after the augmentation process, however the base station itself is modified during the augmentation process to provide the desired enhanced capabilities and/or enhanced performance.

The present invention comprises a system and method for adding a transmit diversity capability to existing cellular base stations while minimizing the scope and complexity of base station modifications and to reduce the quantity and complexity of additional subsystems needed to provide that transmit diversity capability.

The present invention, in one group of embodiments, extends the capability of a base station to provide transmit diversity by employing a Remote Unit which is typically tower-mounted but which employs a conventional passive column array antenna or multiple such antennas. The present invention, in a second group of embodiments, extends the capability of a base station to provide transmit diversity by employing roof-mounted or ground-mounted units along with a tower-mounted conventional passive column array antenna or multiple such antennas. The Remote Unit was referred to as CEB in US patent application No. 60/342,105.

Brief Description of the Figures

The features, objects, and advantages of the present invention will become more apparent from the detailed description which follows, when taken in conjunction with the drawings.

Figures 1-5 show various example embodiments of the present invention.

Fig. 1 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having one MCPA per sector and no transmit diversity and employing CDMA, AMPS and CDPD transmission is converted by adding a low-power signal combiner, a Transmit Diversity Unit, external MCPA, and external Duplexer to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 2 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having two MCPAs per sector and no transmit diversity and employing CDMA, AMPS and CDPD transmission is converted by adding a low-power signal combiner, Transmit Diversity Unit and by re-arranging signals, obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 3 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of almost "any" base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding three Duplexers, a high-power signal combiner, Directional Coupler, Transmit Diversity Unit, and MCPA with external Duplexer, obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 4 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding two Tx bandpass filters, two Directional Couplers, Directional Couplers, Transmit Diversity Unit, MCPA, and a separate Tx Diversity antenna to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 5 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding a Tx low-power combiner, a receive signal 2:1 splitter, Transmit Diversity Unit, MCPA, Duplexer, and Optional Tower-top LNA to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 6 depicts one illustrative augmentation method where two two-column antennas deployed in a space diversity arrangement of a base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding two Tx directional couplers and 2 Tx bandpass filters, two Transmit Diversity Units, and 2 MCPAs to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 7 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having 2 Simplex Tx and 2 Simplex Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding a Tx high-power 2:1 combiner, Directional Coupler, Transmit Diversity Unit, High Power Amplifier, and 2 Duplexers to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 8 depicts one illustrative augmentation method where two two-column antennas deployed in a space diversity arrangement of a low-power base station having Simplex Tx and Rx RF ports and no transmit diversity is converted by adding a Tx Directional Coupler, Transmit Diversity

Unit, MCPA and LPA, 2 Duplexers, and 2 High-Power Phase Shifters to obtain a new system arrangement supporting CDMA Transmit Diversity, Azimuthal Beam Squint and Azimuthal Beamwidth Shaping. Remote and/or autonomous control of the Beam Squint and Beam Shaping are provided by a suitable control system.

Fig. 9 depicts one illustrative augmentation method where an existing polarization diversity antenna arrangement of a base station having Simplex Tx and Rx RF ports and no transmit diversity is converted by adding a Tx Coupler, Transmit Diversity Unit, Remote Unit incorporating two Duplexers, two LNAs, one Tx Power Amplifier, and control system for Remote Electronic Tilt to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 10 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having one Tx-only lower-power port, one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector and no transmit diversity is converted by adding a Transmit Diversity Unit, MCPA, and Duplexer to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 11 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers) and no transmit diversity is converted by adding two Duplexers, two Directional Couplers, 2:1 low-power Tx signal combiner, Transmit Diversity Unit, a separate Tx Diversity antenna, and a Remote Unit incorporating two Duplexers, two LNAs, one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 12 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector and no transmit diversity is converted by adding a Tx Coupler, Transmit Diversity Unit, Remote Unit incorporating two Duplexers, two LNAs, and one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 13 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector and no transmit diversity is converted by adding a Tx Coupler, Transmit Diversity Unit, variable-gain Tx and Rx signal amplifiers, Duplexer, Remote Unit incorporating two Duplexers, two LNAs, and one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 14 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a low-power base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector and no transmit diversity is converted by adding a Tx Coupler, Transmit Diversity Unit, variable-gain Tx and Rx signal amplifiers, Duplexer, Two Remote Units with each one incorporating one Duplexers, one LNA, and one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 15 depicts one illustrative augmentation method where an existing space diversity antenna arrangement of a base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port

per sector and no transmit diversity is converted by adding a Directional Coupler, RF Dummy Load, Duplexer, 1:2 Splitter, Transmit Diversity Unit, variable-gain Tx and Rx signal amplifiers, Duplexer, Two Remote Units with each one incorporating one Duplexers, one LNA, and one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Detailed Description of the Embodiments

The present detailed description hereby expressly incorporates by reference in their entireties US Patent application numbers 09/697770, 60/161918, 60/177653, 60/330,505, and 60/342,105. These previously filed applications employ one or more antenna array systems in order to implement a transmit diversity capability or other additional base station transmission or reception capability. Some of the embodiments in these US patent applications use active antenna array systems. Some cellular network applications do not suggest or permit the use of active antenna array systems. One such example is where a sufficiently low radio transmission frequency is employed by the cellular network, so that the RF cable losses are not significant. Another such example is where the distance between the antenna(s) and the radio base station is very short, and where the antennas are deployed nearby on a rooftop. In such a case, RF cable losses may not be significant and use of an active antenna array system may not be required nor desired. In such cases, it may be advantageous to instead locate all the transmit and receive amplifiers, RF transmit and receive filters, etc. within or nearby the radio base station. Another such example is where very high composite power is required to be transmitted and special transmit amplifier cooling arrangements are required, which may not be suitable for tower-mounted or roof-mounted active antenna array applications.

One or more of the previous US Patent applications listed previously included descriptions of embodiments providing transmit diversity capability for CDMA base stations. These embodiments employ various signal processing means to generate or synthesize the second or Diversity transmit signal, such as time delay and/or phase sweep transforms.

Existing base station antenna arrangements may utilize receive diversity antennas, e.g., to combat the adverse effects of multipath propagation. A prevailing cellular base station configuration incorporates a space diversity antenna pair in each sector.

It is known in the art that transmit diversity can provide enhanced capacity and/or coverage for CDMA networks. An upgrade is desired in many of these cases in order to enhance the capacity for a particular sector by adding transmit diversity. The benefit to the sector of the enhanced capacity can range from 20% to 200%.

Various embodiments are illustrated in Figures 1-15.

Fig. 1 illustrates an augmentation method that modifies an existing base station system configuration but does not change the antenna arrangement for the passive antennas. The antenna arrangement comprises a main antenna and diversity antenna. Augmentation of the base station in Fig. 1 converts an existing base station without transmit diversity to an augmented base station having receive space diversity and transmit space diversity.

Initially, the existing base station arrangement includes a main antenna that permits transmission and reception over the same Main antenna. A single cable extends from the main antenna, located at the top of a building and connects to a Main Duplexer located in the base station. The Main Duplexer serves as a coupler that allows the simultaneous transmission and reception of two signals using the same Main antenna. To transmit a signal from the base station to a mobile unit along the forward link, the base station transceiver system sends a transmit signal comprised of either a CDMA, CDPD, or AMPS signal via a transmission cable Tx1 through a multicarrier linear power amplifier LPA to a Tx Main input terminal of the Main Duplexer. The Main Duplexer then sends the transmit signal over an RF cable to the Main Antenna, where the transmit signal is radiated to the mobile unit. When the mobile unit transmits a signal to the base station along the reverse link, the receive signal arrives at the Main antenna, which then sends the receive signal to the Main Duplexer via an RF cable. The Duplexer sends the receive signal to the base station transceiver subsystem by directing the signal over the receive line Rx1.

In the embodiment of Fig. 1, the secondary Diversity antenna is a passive column array deployed in a space diversity configuration. However, the scope of the embodiment of Fig. 1 is not limited to this exemplary arrangement. Other types of secondary antenna arrangements may be employed alone or in combination, such as a polarization diversity antenna arrangement.

Within the existing base station antenna arrangement of Fig. 1, a single RF cable extends from the secondary Diversity antenna to the Diversity Duplexer. Another cable Rx2 extends from the Diversity Duplexer to the receive input terminal of the base station transceiver subsystem.

Both the Main Antenna and Diversity Antenna are passive.

In order to convert the existing base station system to an augmented base station system providing transmit diversity, several modifications are made to the Tx path to the Diversity Duplexer. A multicarrier linear amplifier MCPA is connected via cable to the Tx Diversity port of the Diversity Duplexer. The output of the Transmit Diversity Unit TDU of the Interface and Control Unit ICU is connected to the input terminal of the MCPA. In turn, a low-power combiner drives the input terminal of the TDU. The various input signals connected to the low-power combiner comprise the various single carrier CDMA transmit diversity signals to be radiated by the Diversity antenna.

Fig. 2 illustrates an augmentation method that modifies an existing base station system configuration but does not change the antenna arrangement for the passive antennas. The antenna arrangement comprises a main antenna and a diversity antenna. Augmentation of the base station in Fig. 2 converts an existing base station without transmit diversity to an augmented base station having receive space diversity and transmit space diversity.

Initially, the existing base station arrangement includes a main antenna that permits transmission and reception over the same Main antenna. A single cable extends from the main antenna, located at the top of a building and connects to a Main Duplexer located in the base station. The Main Duplexer serves as a coupler that allows the simultaneous transmission and reception of two signals using the same Main antenna. To transmit a signal from the base station to a mobile unit along the forward link, the base station transceiver system sends a transmit signal comprised of either a CDMA, CDPD, or AMPS signal via a transmission cable Tx1 through a multicarrier linear power amplifier LPA-2 to a Tx Main input terminal of the Main Duplexer. The Main

Duplexer then sends the transmit signal over an RF cable to the Main Antenna, where the transmit signal is radiated to the mobile unit.

An alternative means is provided by the existing base station arrangement for transmission from the base station to the mobile unit. A second set of transmission signals can be sent via multicarrier linear amplifier LPA-1 to the Diversity antenna, in a similar way that this was accomplished via LPA-2 and the Main antenna.

When the mobile unit transmits a signal to the base station along the reverse link, the receive signal arrives at the Main antenna, which then sends the receive signal to the Main Duplexer via an RF cable. The Duplexer sends the receive signal to the base station transceiver subsystem by directing the signal over the receive line Rx1.

In the embodiment of Fig. 2, the secondary Diversity antenna is a passive column array deployed in a space diversity configuration. However, the scope of the embodiment of Fig. 2 is not limited to this exemplary arrangement. Other types of secondary antenna arrangements may be employed alone or in combination, such as a polarization diversity antenna arrangement.

Within the existing base station antenna arrangement of Fig. 2, a single RF cable extends from the secondary Diversity antenna to the Diversity Duplexer. Another cable Rx2 extends from the Diversity Duplexer to the receive input terminal of the base station transceiver subsystem.

Both the Main Antenna and Diversity Antenna are passive.

In order to convert the existing base station system to an augmented base station system providing transmit diversity, a few modifications are made to the Tx path to the Diversity Duplexer. The existing multicarrier linear amplifier LPA-1 which was connected via a cable to the Tx Diversity port of the Diversity Duplexer is still in place. The output of the Transmit Diversity Unit TDU of the Interface and Control Unit ICU is now connected to the input terminal of LPA-1. In turn, a low-power combiner drives the input terminal of the TDU. The various input signals connected to the low-power combiner comprise the various single carrier CDMA transmit diversity signals to be radiated by the Diversity antenna.

Fig. 3 illustrates an augmentation method that modifies an existing base station system configuration but does not change the antenna arrangement for the passive antennas. The antenna arrangement comprises a main antenna and diversity antenna. Augmentation of the base station in Fig. 3 converts an existing base station without transmit diversity to an augmented base station having receive space diversity and transmit space diversity.

Initially, the existing base station arrangement includes a Main antenna that permits transmission and reception over the same Main antenna. A single cable extends from the Main antenna, located at the top of a building and connects to the base station BTS.

Within the existing base station antenna arrangement of Fig. 3, a single RF cable extends from the secondary Diversity antenna to the Diversity port of the BTS. It provides a means for reception of the Diversity Receive signals, as well as transmission of signals on Tx Channels 1, 3 and 5.

Both the Main Antenna and Diversity Antenna are passive.

In order to convert the existing base station system to an augmented base station system providing transmit diversity, several modifications are made to the RF path to the Diversity Antenna. The Diversity Duplexer, placed in the High Power Amplifier Rack, is connected to the Diversity Antenna. A multicarrier linear amplifier MCPA is connected via cable to the Tx Diversity port of the Diversity Duplexer. The output of the Transmit Diversity Unit TDU of the Interface and Control Unit ICU is connected to the input terminal of the MCPA. In turn, the sample port of a Directional Coupler placed inside the RF Interface Unit RFIU drives the TDU.

The main signal driving the Directional Coupler of the RFIU is derived by first combining the various transmit signals coming from the two respective Tx ports of the base station BTS. The signal combining is performed via the two respective Duplexers and High Power Combiner located in the RFIU.

To transmit a signal from the base station to a mobile unit along the forward link, the existing base station transceiver system sends a transmit signal comprised of a CDMA signal (e.g., Channels 2, 4, or 6) via the Main Tx/Rx port of the base station BTS to a Duplexer located in the RF Interface Unit RFIU and from there to a High Power Combiner in the RFIU, then through a Directional Coupler to a Main Duplexer located in the RFIU. The Main Duplexer then sends the transmit signal over an RF cable to the Main Antenna, where the transmit signal is radiated to the mobile unit.

When the mobile unit transmits a signal to the base station along the reverse link, the receive signal arrives at the Main antenna, which then sends the receive signal to the Main Duplexer via an RF cable. The Duplexer sends the receive signal to the base station transceiver subsystem by directing the signal through another Duplexer in the RFIU to the Main RF port of the BTS.

Within the augmented base station system arrangement of Fig. 3, a single RF cable extends from the secondary Diversity antenna to the Diversity Duplexer in the High Power Amplifier Rack. Another cable extends from the Diversity Duplexer to the Duplexer in the RFIU connected to the Diversity RF port of the BTS.

In the embodiment of Fig. 3, the secondary Diversity antenna is a passive column array deployed in a space diversity configuration. However, the scope of the embodiment of Fig. 3 is not limited to this exemplary arrangement. Other types of secondary antenna arrangements may be employed alone or in combination, such as a polarization diversity antenna arrangement.

The architecture of the embodiment of Fig. 3 is compatible with any base station architecture, since it does not need a low-power RF connection point inside the existing base station. This reduces cost and complexity.

Fig. 4 illustrates an augmentation method that modifies an existing base station system configuration and changes the antenna arrangement for the passive antennas. The existing antenna arrangement comprises a main antenna and diversity antenna, however the augmented arrangement adds a third antenna for transmit diversity. Augmentation of the base station in Fig. 4 converts an existing base station without transmit diversity to an augmented base station having receive space diversity and transmit space diversity.

The existing base station configuration for Figure 4 is identical to that of Figure 3. The differences are with regard to the augmented base station and antenna configurations.

In order to convert the existing base station system to an augmented base station system providing transmit diversity, a multicarrier linear amplifier MCPA is connected via cable to the Tx Diversity antenna. The output of the Transmit Diversity Unit TDU of the Interface and Control Unit ICU is connected to the input terminal of the MCPA. In turn, the output port of the low-level combiner in the RFIU sample drives the TDU.

The signals feeding the low-level combiner in the RFIU are bandpass filtered, after being derived from two respective Directional Couplers in the RFIU. The Directional Couplers are fed by the two RF ports of the BTS known as Main and Diversity.

To transmit a signal from the base station to a mobile unit along the forward link, the base station transceiver system sends a transmit signal comprised of a CDMA signal (e.g., Channels 2, 4, or 6) via the Main Tx/Rx port of the base station BTS to a Directional Coupler in the RFIU, then over an RF cable to the Main Antenna, where the transmit signal is radiated to the mobile unit.

When the mobile unit transmits a signal to the base station along the reverse link, the receive signal arrives at the Main antenna, which then sends the receive signal to the Main RF port of the BTS.

In the embodiment of Fig. 4, the Tx Diversity antenna is a passive column array deployed in a space diversity configuration. However, the scope of the embodiment of Fig. 4 is not limited to this exemplary arrangement. Other types of secondary antenna arrangements may be employed alone or in combination, such as a polarization diversity antenna arrangement.

One possible disadvantage is that it may require use of 3 antennas per sector.

An embodiment related to the embodiment of Figure 4 was included in US Patent Application 60/330,505.

Fig. 5 illustrates an augmentation method that modifies an existing base station system configuration but does not change the antenna arrangement for the passive antennas. The antenna arrangement comprises a main antenna and diversity antenna. Augmentation of the base station in Fig. 5 converts an existing base station without transmit diversity to an augmented base station having receive space diversity and transmit space diversity.

Initially, the existing base station arrangement includes a Main antenna that permits transmission and reception over the same Main antenna. A single cable extends from the Main antenna, located at the top of a building and connects via an Optional tower-mounted LNA to the base station BTS.

Within the existing base station antenna arrangement of Fig. 5, a single RF cable extends from the secondary Diversity antenna to the Diversity port of the BTS. It provides a means for reception of the Diversity Receive signals, as well as transmission of signals on some of the available the Tx Channels.

Both the Main Antenna and Diversity Antenna are passive.

The existing base station configuration for Figure 5 is almost identical to that of Figure 3. The differences are with regard to the augmented base station.

In order to convert the existing base station system to an augmented base station system providing transmit diversity, several modifications are made to the RF path to the Diversity Antenna. The Diversity Duplexer, placed in the High Power Amplifier Rack, is connected to the Diversity Antenna. A multicarrier linear amplifier MCPA is connected via cable to the Tx Diversity port of the Diversity Duplexer. The output of the Transmit Diversity Unit TDU of the Interface and Control Unit ICU is connected to the input terminal of the MCPA. In turn, a low-power combiner placed inside the RF Interface Unit RFIU drives the TDU.

The signals driving the inputs of the low-power combiner in the RFIU are derived by sampling the various transmit signals coming from the two respective Tx ports of the RF UNIT in the base station BTS.

To transmit a signal from the base station to a mobile unit along the forward link, the base station transceiver system sends a transmit signal comprised of a CDMA signal via the Main Tx/Rx port of the base station BTS to a high-power Combiner located in the modified BTS. The Combiner then sends the transmit signal over an RF cable to the Main Antenna, where the transmit signal is radiated to the mobile unit.

When the mobile unit transmits a signal to the base station along the reverse link, the receive signal arrives at the Main antenna, is amplified by a tower-mounted LNA, which then sends the receive signal to the High Power Combiner via an RF cable. It is to be noted that the Optional tower-mounted LNA does not have any role in enhancing the Forward Link. The Combiner sends the receive signal to the base station transceiver subsystem through the RF UNIT.

Within the augmented base station system arrangement of Fig. 5, a single RF cable extends from the secondary Diversity antenna to the Diversity Duplexer in the High Power Amplifier Rack. Another cable extends from the Diversity Duplexer to a Splitter in the RFIU, which in turn is connected to the Diversity RF port of the RF UNIT in the BTS.

In the embodiment of Fig. 5, the secondary Diversity antenna is a passive column array deployed in a space diversity configuration. However, the scope of the embodiment of Fig. 5 is not limited to this exemplary arrangement. Other types of secondary antenna arrangements may be employed alone or in combination, such as a polarization diversity antenna arrangement.

One possible disadvantage of the embodiment of Figure 5 is that it requires a low-power RF connection point where RF carriers are available. It also requires that a high-power combiner be installed inside the base station.

Fig. 6 illustrates an augmentation method where there are two two-column antennas deployed in a space diversity arrangement of a base station having two Duplexed Tx/Rx RF ports per sector (for two groups of CDMA carriers). As was the case for previously disclosed embodiments, no transmit diversity is provided by the existing base station. The existing single-column antennas

are replaced by a two-column antenna which has approximately the same physical size as the existing single-column antennas.

The rest of the augmentation process involves adding two Tx directional couplers and 2 Tx bandpass filters, which in turn feed the respective Tx signals to two Transmit Diversity Units. Two MCPAs placed at the outputs of the Transmit Diversity Units allow the augmented system to support CDMA Transmit Diversity.

A primary advantage of the embodiment of Figure 6 is that there are no Duplexer losses, increasing the available Tx power.

Fig. 7 illustrates an augmentation method where there are two single-column antennas deployed in a space diversity arrangement of a base station having 2 Simplex Tx and 2 Simplex Rx RF ports per sector (for two groups of CDMA carriers). As was the case for previously disclosed embodiments, no transmit diversity is provided by the existing base station.

The augmentation process involves connecting and adding a Tx high-power 2:1 combiner to the base station Tx ports. The combiner feeds the all-carriers Tx signal to the Directional Coupler, which samples a low level signal and feeds it to the Transmit Diversity Unit. A High Power RF Amplifier provides the high-power Transmit Diversity signal. The two Duplexers which are connected to the Main and Diversity antennas isolate the high-power Tx and low-power Rx signals, and facilitate a new system arrangement supporting CDMA Transmit Diversity using the existing antennas.

Fig. 8 illustrates an augmentation method which affords two high-value capabilities: Azimuthal Beam Squint and Azimuthal Beamwidth Shaping. These important features allow interference and Soft handoff management as well as load management among the sectors of a base station, to afford higher capacity and equipment utilization for cell sites with uneven sector loading.

The augmentation process involves replacing the existing two single-column antennas with two two-column antennas. A Phase Shifter driven by a remote control system which may be either manually or automatically controlled affects the antenna pattern for the two-column structure by adjusting the main lobe boresight azimuth.

The embodiment according to Fig. 8 is implemented in conjunction with a low-power base station having Simplex Tx and Rx RF ports. It is also possible to deploy this capability with other base station configurations.

The augmentation process also involves adding a Tx Directional Coupler, whose coupled port in turn drives the Transmit Diversity Unit (TDU). The TDU in turn drives the MCPA. The mainline signal from the Tx Directional Coupler in turn drives the LPA. The two Duplexers connected to the Main and Diversity antennas isolate the high-power Tx and low-power Rx signals, and facilitate a new system arrangement supporting CDMA Transmit Diversity, Azimuthal Beam Squint and Azimuthal Beamwidth Shaping. Remote and/or autonomous control of the Beam Squint and Beam Shaping are provided by a suitable control system, described in previous embodiments.

Fig. 9 illustrates an augmentation method which generally affords better Tx power amplifier efficiency than other approaches. This embodiment employs a Remote Unit which is intended to be installed nearby the antenna(s). The loss encountered for the RF cable between the Remote Unit and antenna will be thereby typically reduced. This particular embodiment is particularly appropriate for urban areas with difficult zoning challenges, since only a single antenna per sector is required to implement Transmit Diversity. The low loss of the Rx cables provides an enhanced Noise Figure for the Reverse link.

Most of the remaining embodiments (shown in Figure 11-15) also employ the Remote Unit, and the benefits of a tower-top Remote Unit accrue to the other embodiments as well.

This embodiment employs a base station having Simplex Tx and Simplex Rx RF ports. The augmentation process involves adding a Tx Coupler, and the coupled port feeds the Transmit Diversity Unit (TDU). The TDU in turn feeds a Diversity Tx signal to the Remote Unit. Since it incorporates two Duplexers, two LNAs, one Tx Power Amplifier, and a control system for Remote Electronic Tilt, it allows easier site optimization. This embodiment also supports CDMA Transmit Diversity.

Fig. 10 illustrates an augmentation method whereby only one additional Tx Power Amplifier per sector is employed. The embodiment requires the availability of a Tx-only lower-power port at the base station. This approach also employs a Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector. This embodiment involves feeding the TDU from the low-power TX only RF port of the base station. The TDU in turn drives the MCPA and the Duplexer connected to the Diversity Antenna allows use of only two antennas per sector.

One possible disadvantage of the embodiment of Figure 10 is that it requires a low-power RF connection point where RF carriers are available.

Fig. 11, like the previous embodiment, illustrates an augmentation method whereby only one additional Tx Amplifier per sector is employed, and its output looses are minimized. It has the advantage of being a more universal augmentation solution since it does not require specialized base station connections. One possible disadvantage is that it requires a third antenna per sector. The augmentation process involves adding two Duplexers near the base station Duplex RF ports. In turn, two Directional Couplers sample a low-power Tx signal, feeding it to a 2:1 low-power Tx signal combiner, and on to the Transmit Diversity Unit. In this embodiment, the separate Tx Diversity antenna is fed by the Remote Unit incorporating two Duplexers, two LNAs, and one Tx Power Amplifier. The LNAs reduce the system noise figure and help balance the radio link, once the Transmit Diversity has made an impact on the Forward Link.

Fig. 12 also employs a Remote Unit. This embodiment is appropriate in the event that all the CDMA carriers exist on one RF port of the base station. For this augmentation method, a base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector is employed. The augmentation process involves adding a Tx Coupler at a low RF power sampling point inside the base station. The couler feeds the Transmit Diversity Unit, which in turn feeds the Tx Power Amplifier in the Remote Unit. As before, the Remote Unit incorporates two Duplexers, two LNAs, and one Tx Power Amplifier. One possible disadvantage of the embodiment of Figure 12 is that it requires a low-power RF connection point where RF carriers are available.

Fig. 13 illustrates an augmentation method whereby the Tx power levels for both Main and Diversity Tx are set within the Remote Unit itself. Again the two existing column antennas in a space diversity arrangement are employed, in conjunction with a Remote Unit. The augmentation process involves of a base station having one Duplexed Tx/Rx RF port and one Simplex Rx RF port per sector and no transmit diversity is converted by adding a Tx Coupler, Transmit Diversity Unit, variable-gain Tx and Rx signal amplifiers, Duplexer, Remote Unit incorporating two Duplexers, two LNAs, and one Tx Power Amplifier to obtain a new system arrangement supporting CDMA Transmit Diversity.

Fig. 14 has one major difference from the embodiment shown in Fig. 13. It employs a Modular Remote Unit, which is split into two identical halves. This architecture facilitates maintenance and reduces sector down-time.

Fig. 15 illustrates an augmentation method whereby the augmentation system itself can be quickly removed from service and the base station returned to its initial configuration quickly if desired. This approach employs a non-radiating RF Load to dissipate the existing base station Tx power. The Coupler and Duplexer at the base station's Tx1/Rx1 RF port help to sample the Tx signal so it can drive the TDU. Variable-gain Tx and Rx signal amplifiers help to set the appropriate base station RF interface levels.

Figure 1
Block Diagram per one Sector

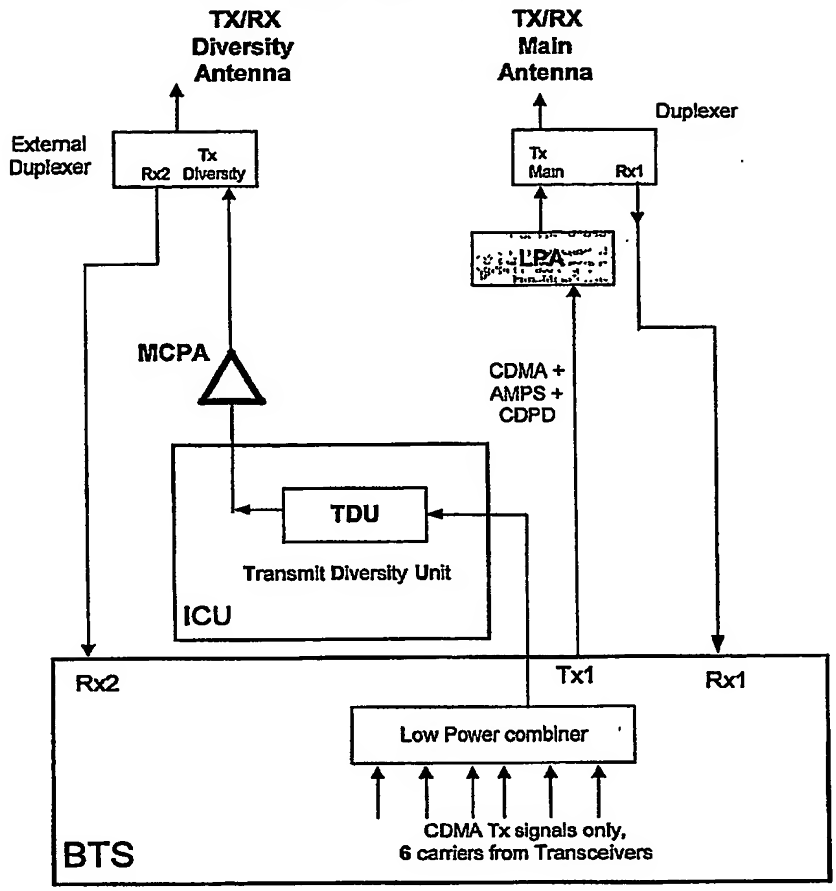


Figure 2
Block Diagram per One Sector

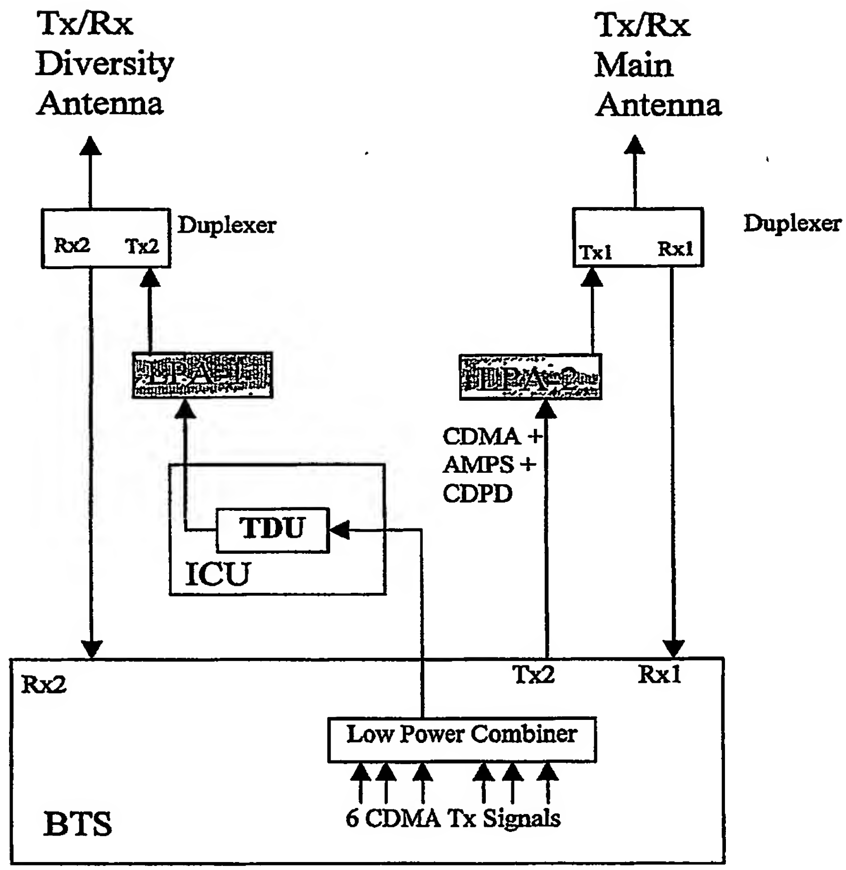


Figure3
Block Diagram per One sector

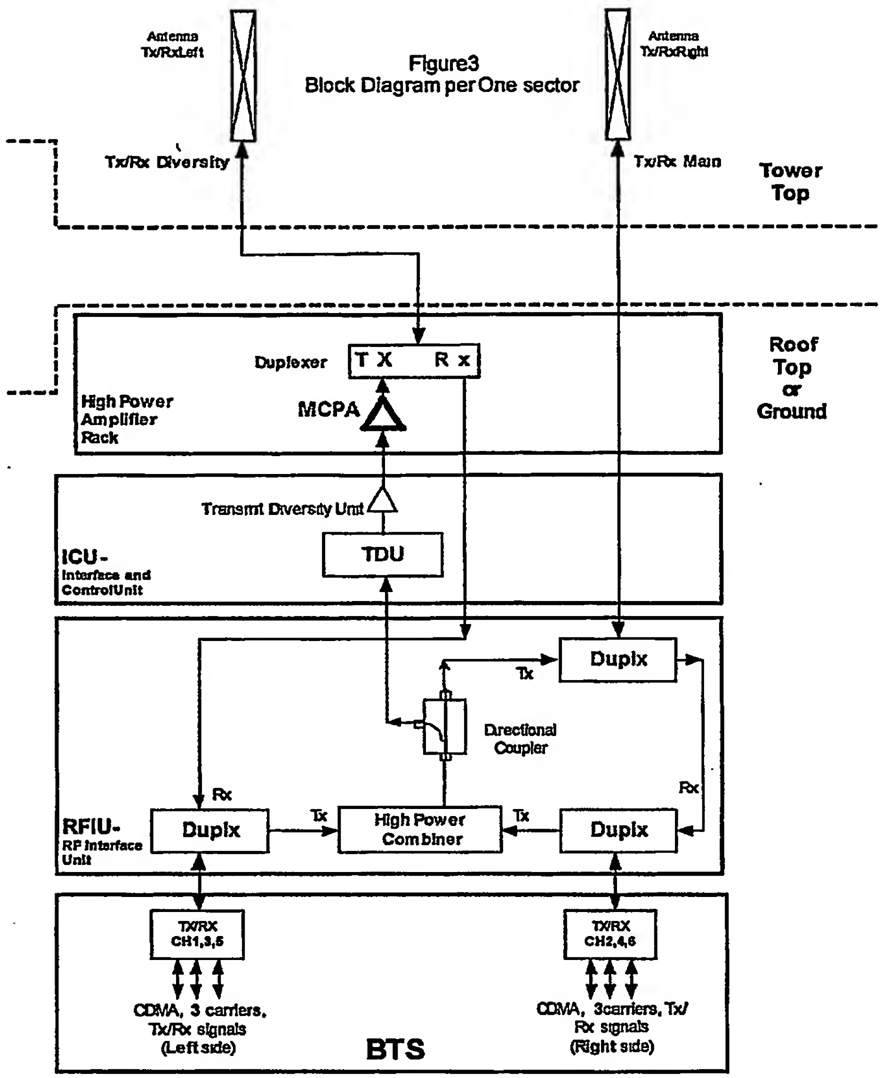


Figure 4
Block Diagram per One sector

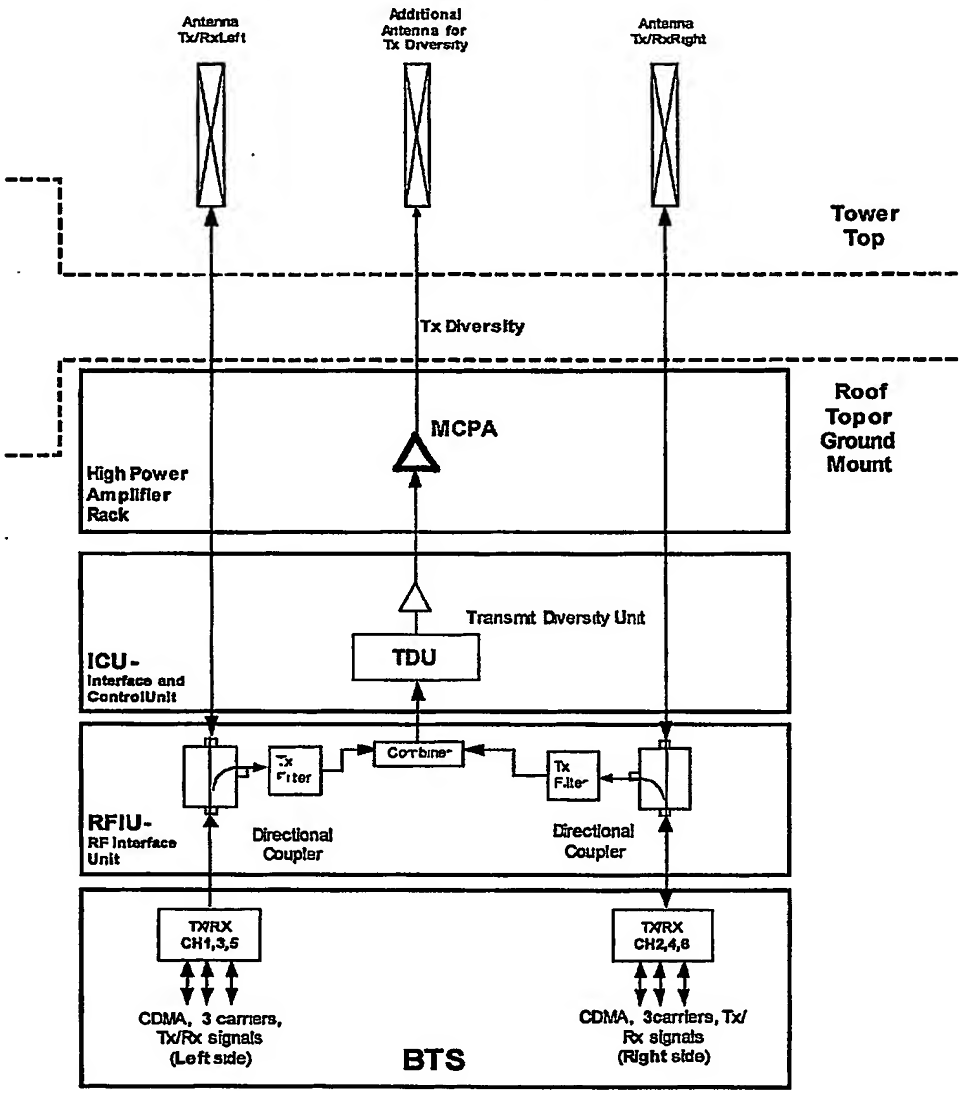


Figure 5
Block Diagram per One sector

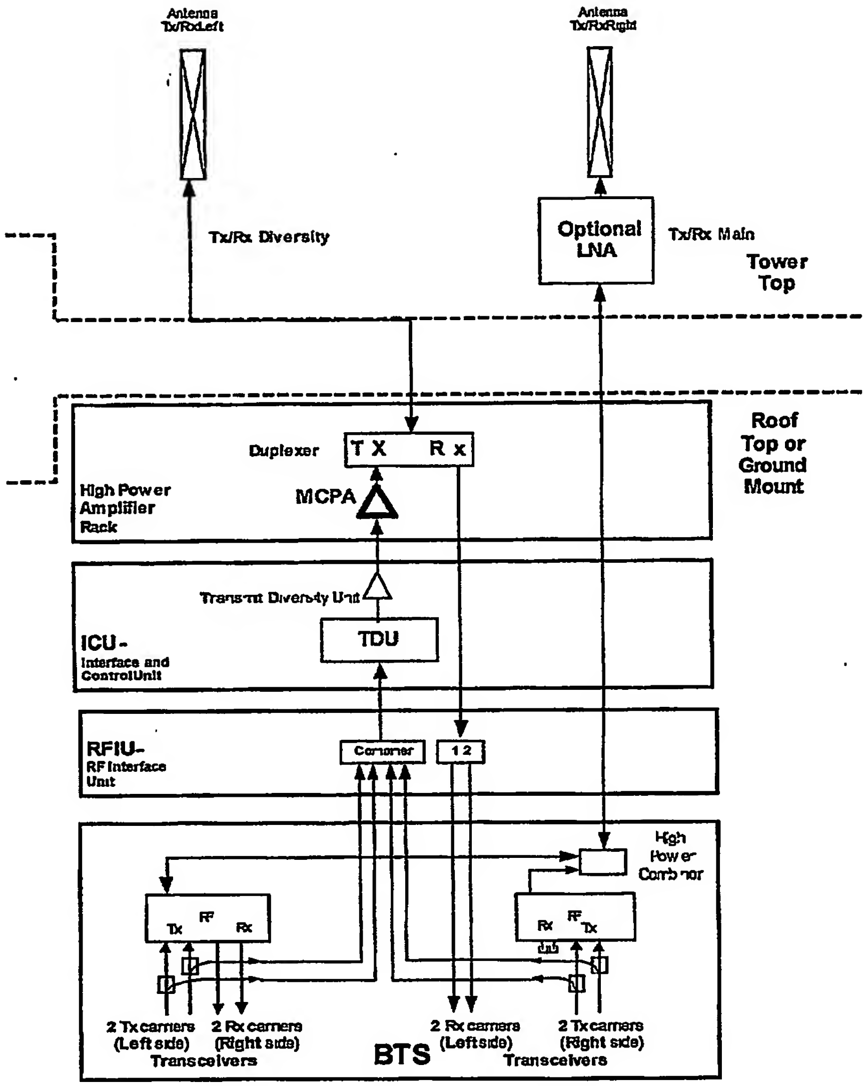
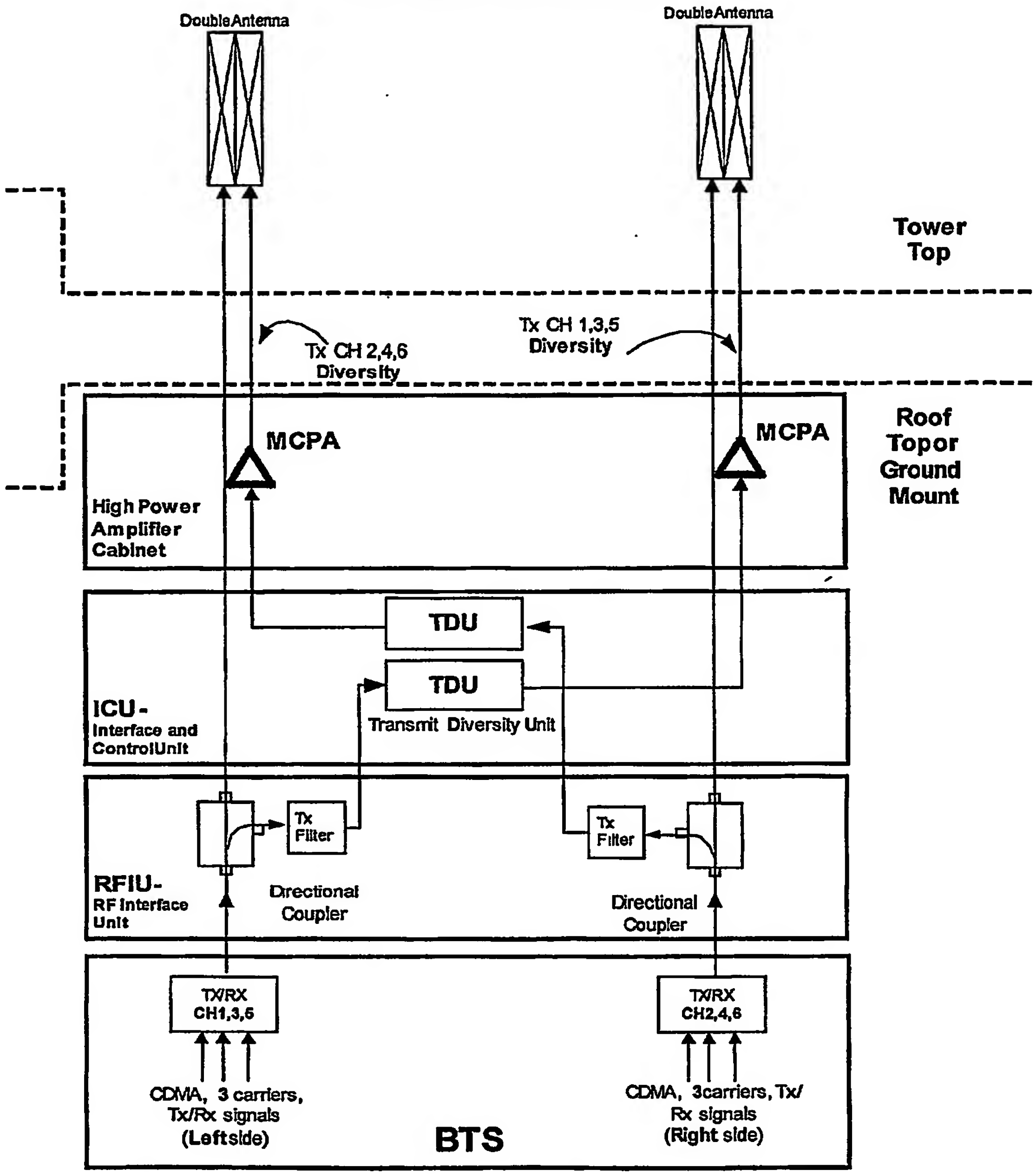


Figure 6

Block Diagram per One Sector



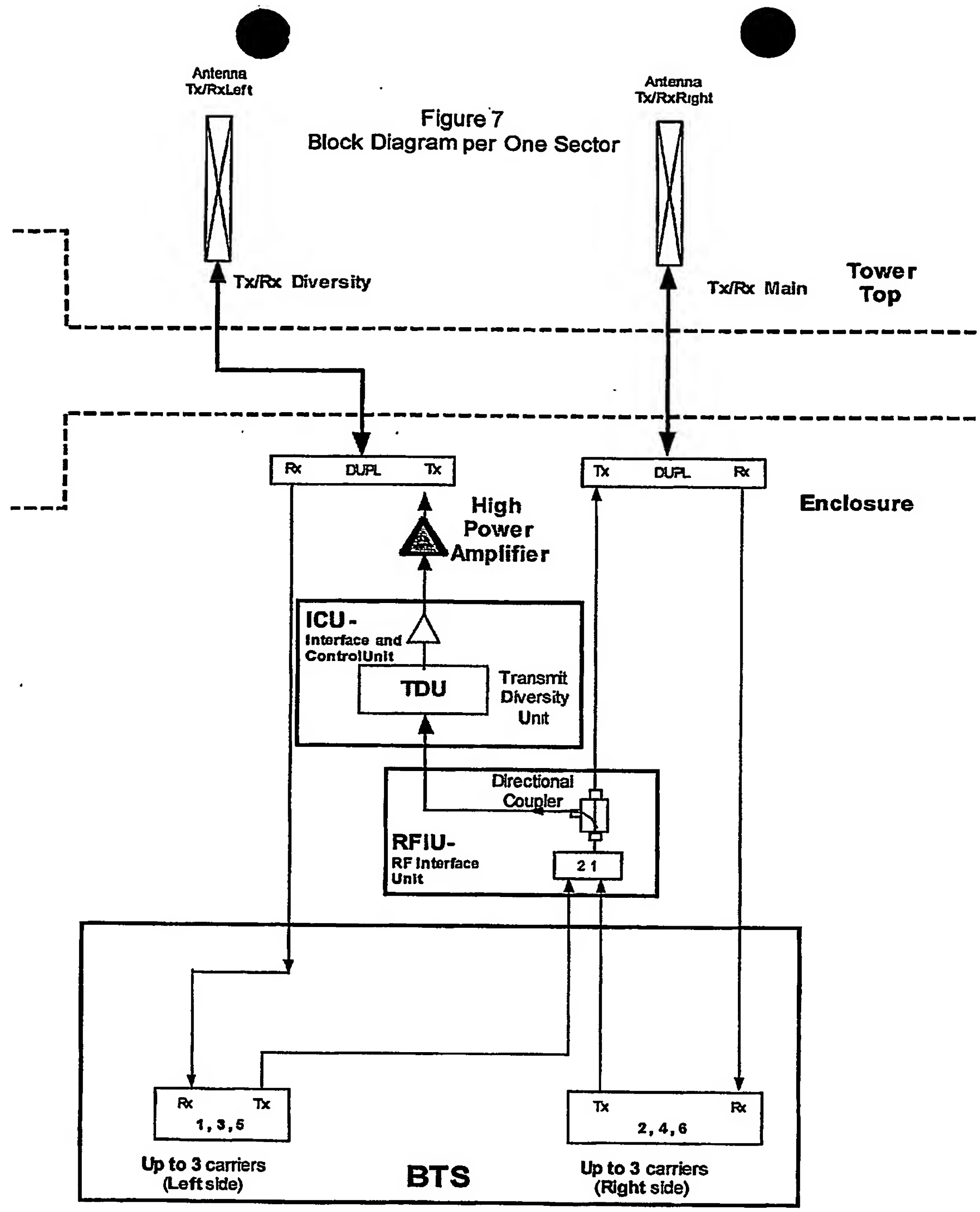


Figure 7
Block Diagram per One Sector

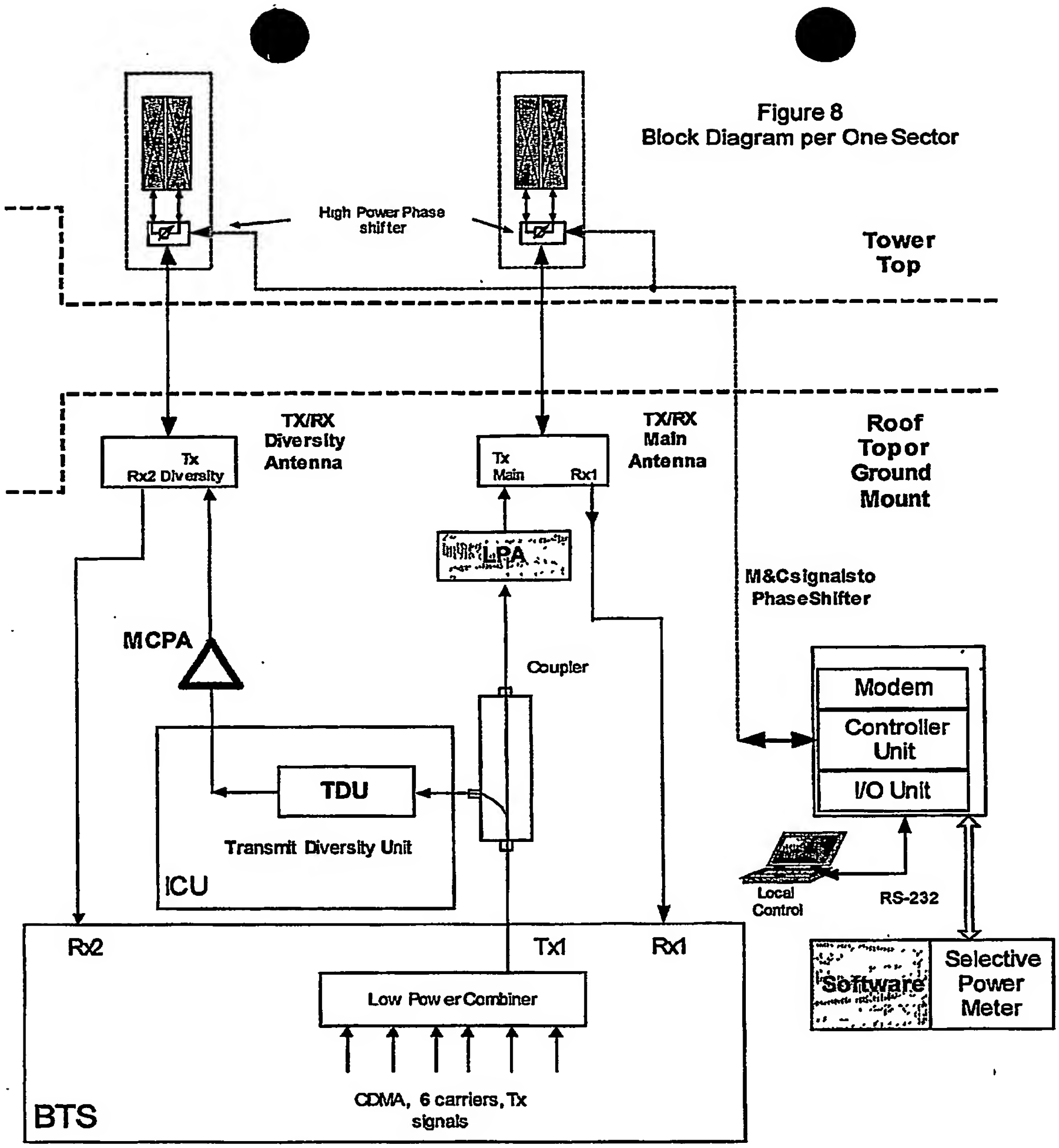


Figure 8
Block Diagram per One Sector

Figure 9

Block Diagram per One Sector

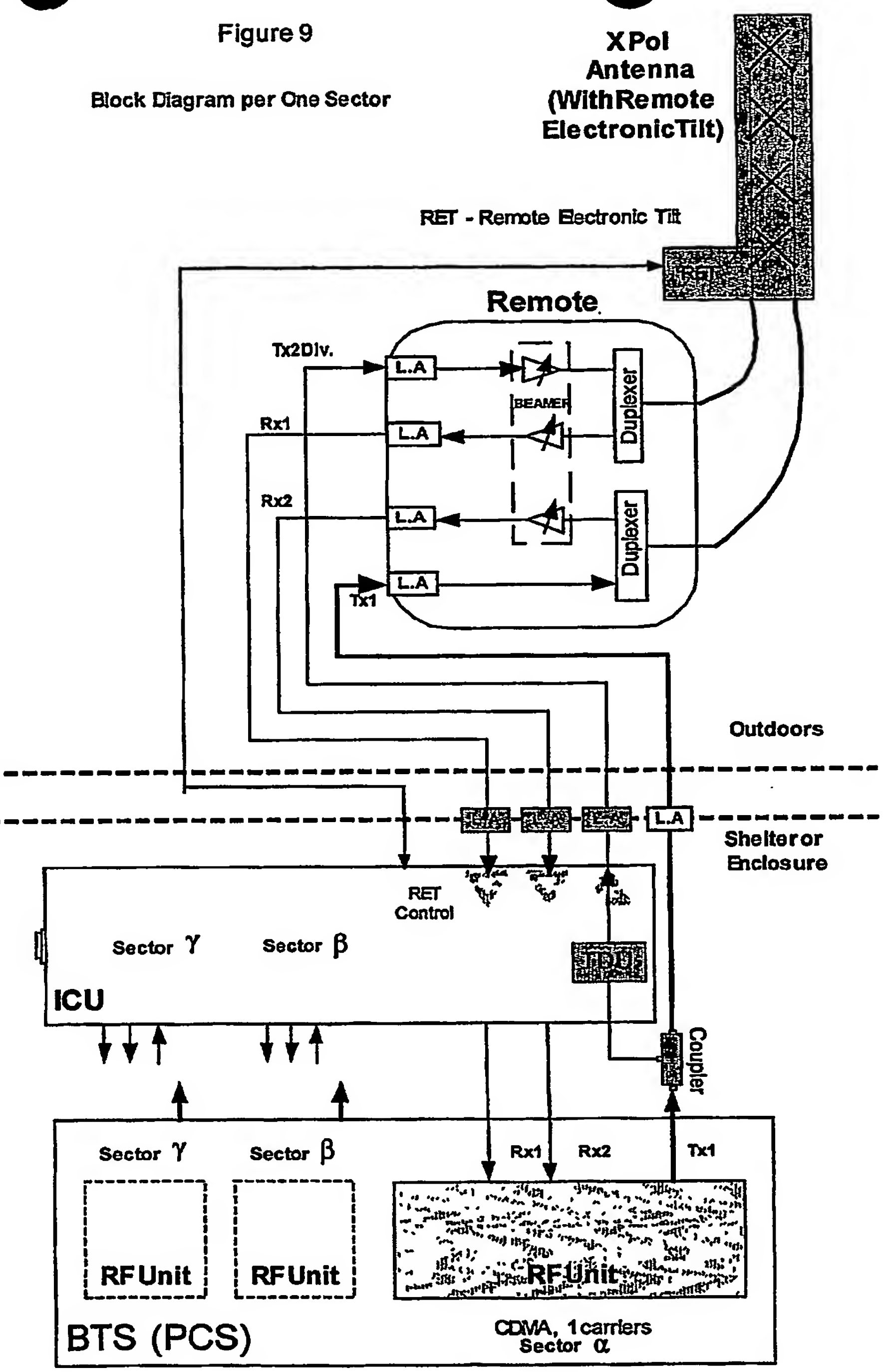


Figure10
Block Diagram per One Sector

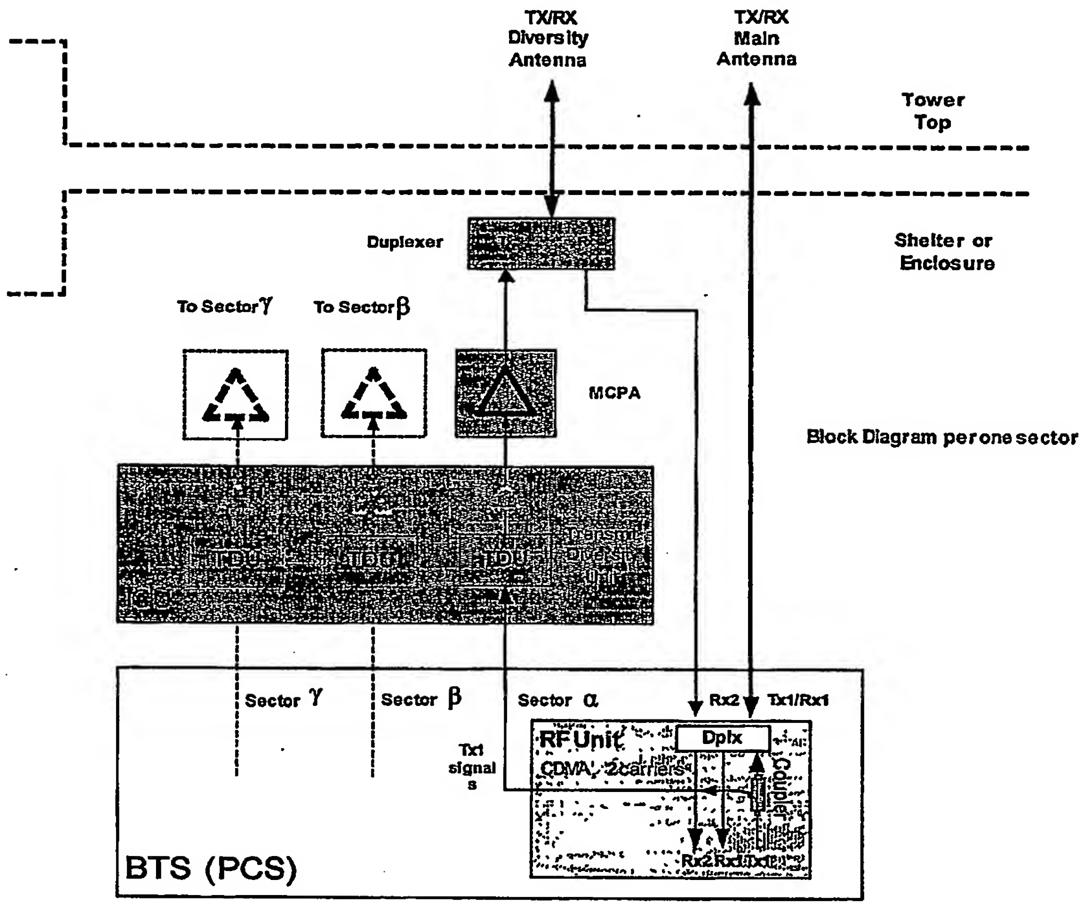


Figure 11
Block Diagram per one sector

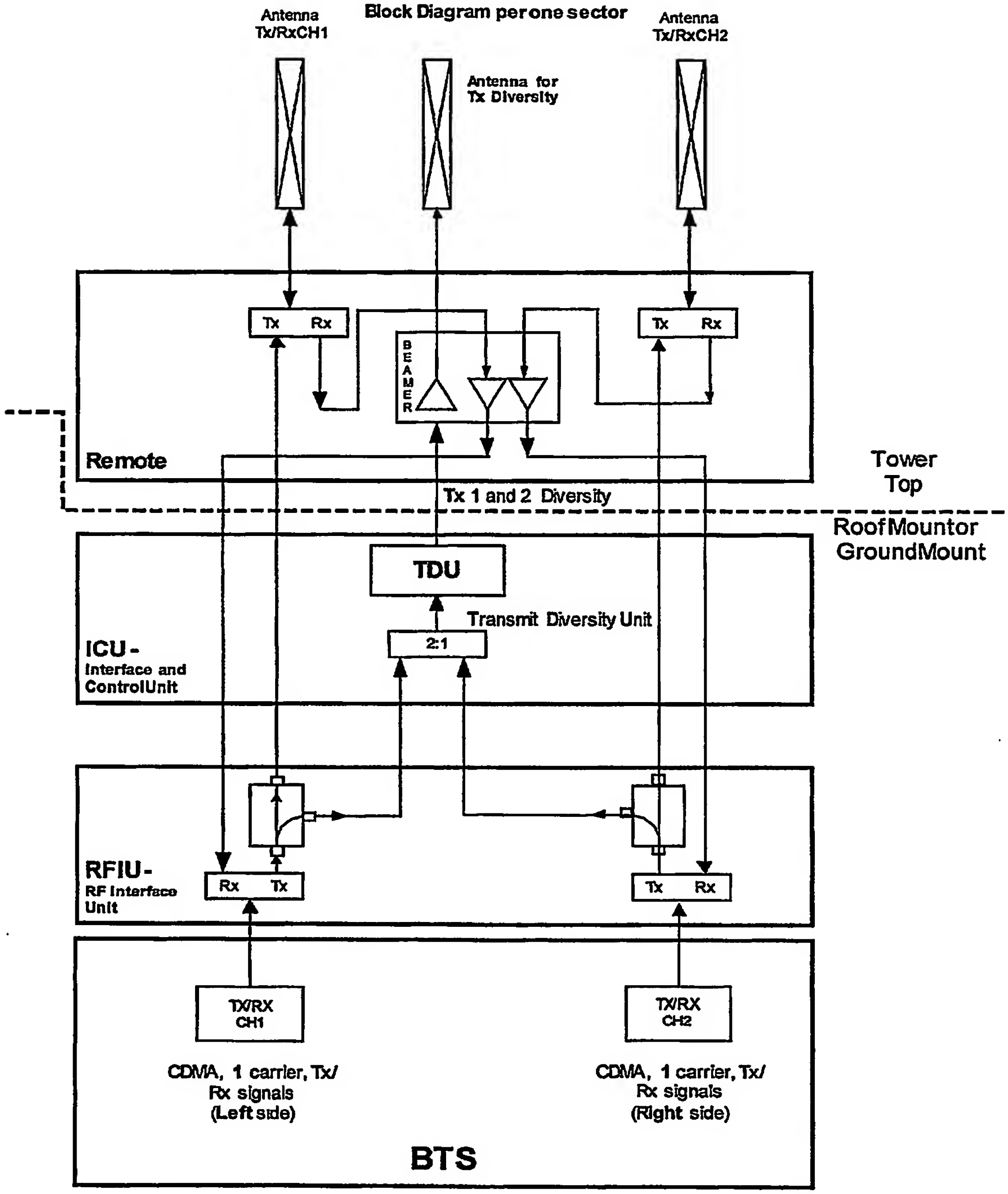


Figure12
Block Diagram per One
Sector

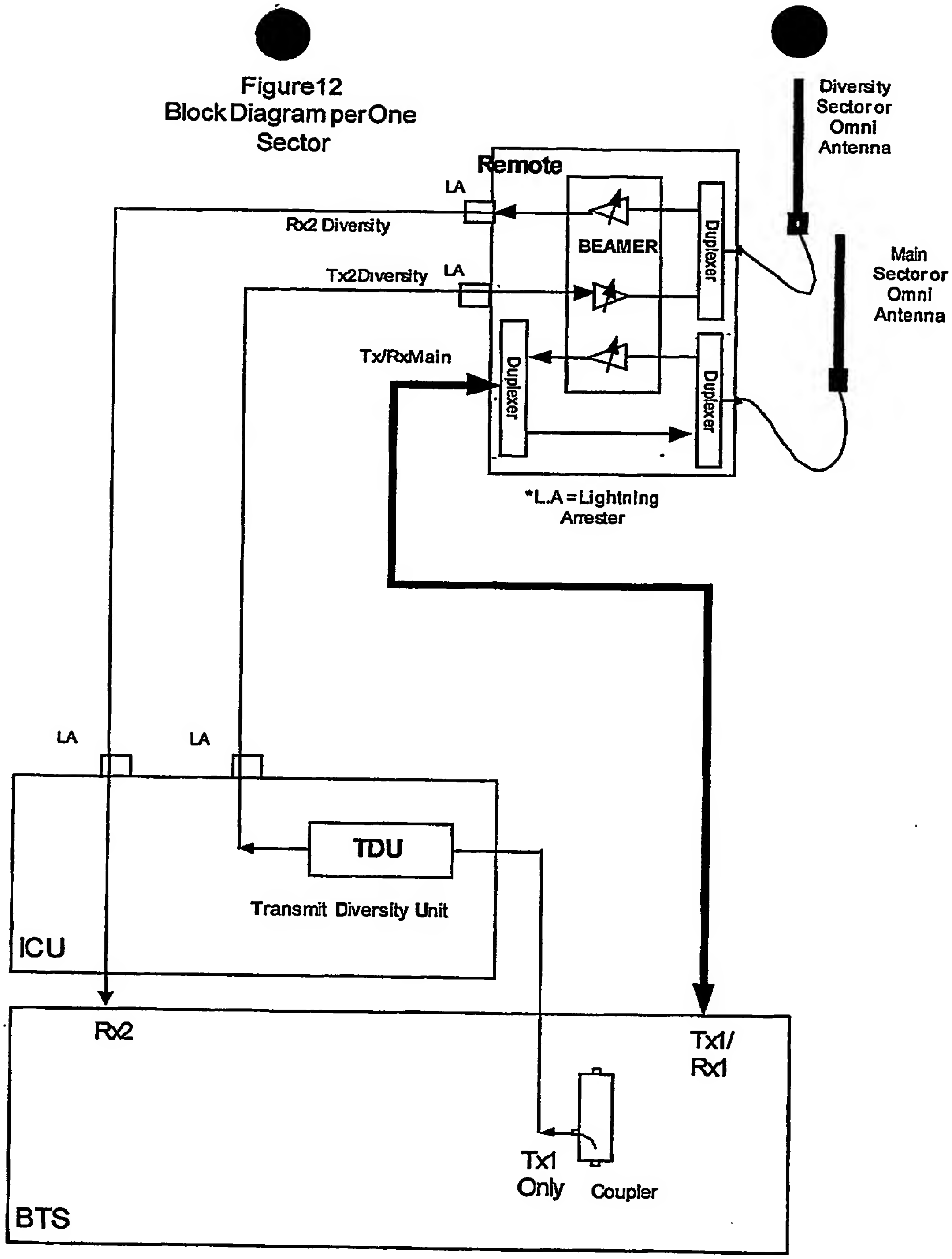


Figure13
Block Diagram perone Sector

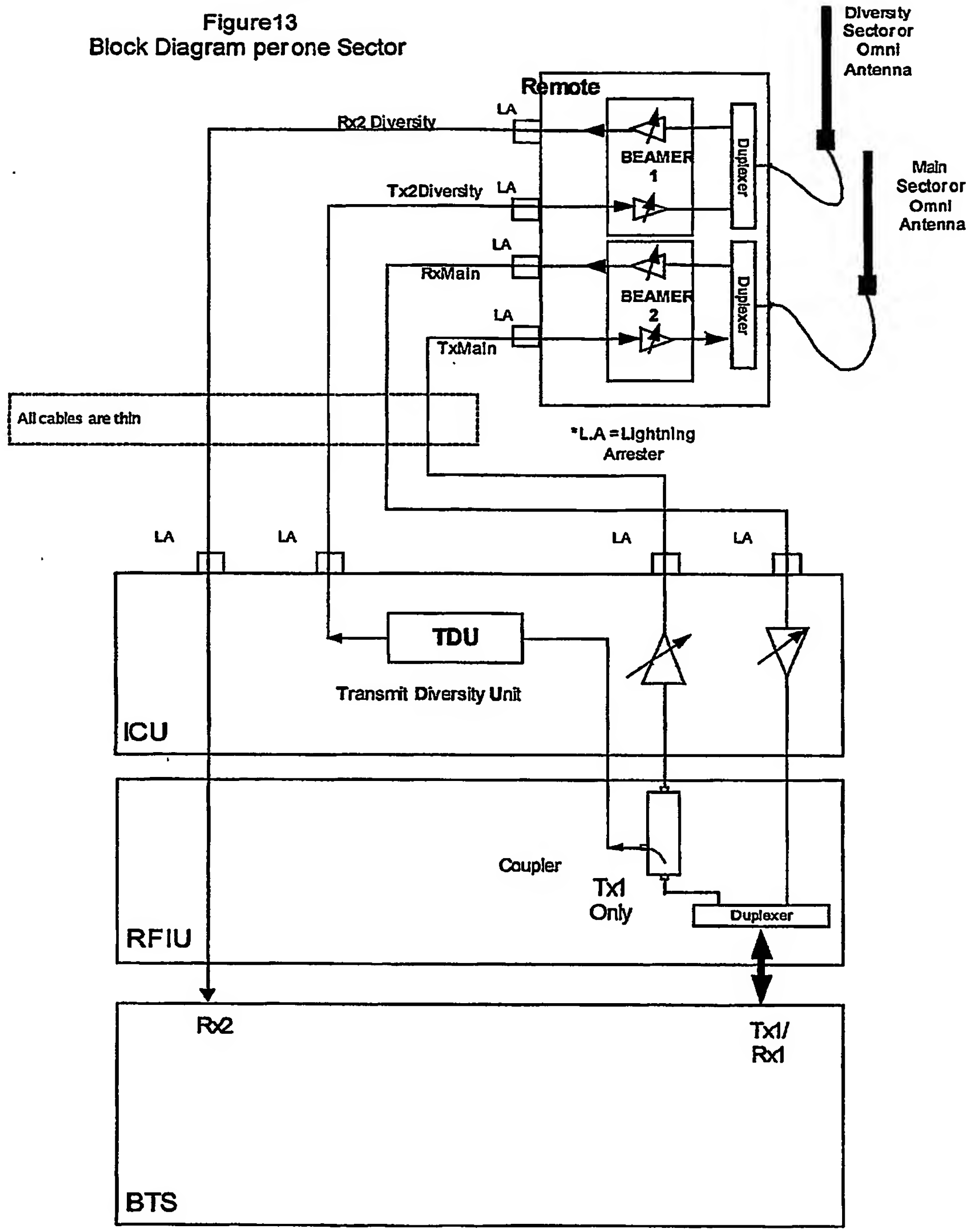


Figure 14
Block Diagram per One Sector

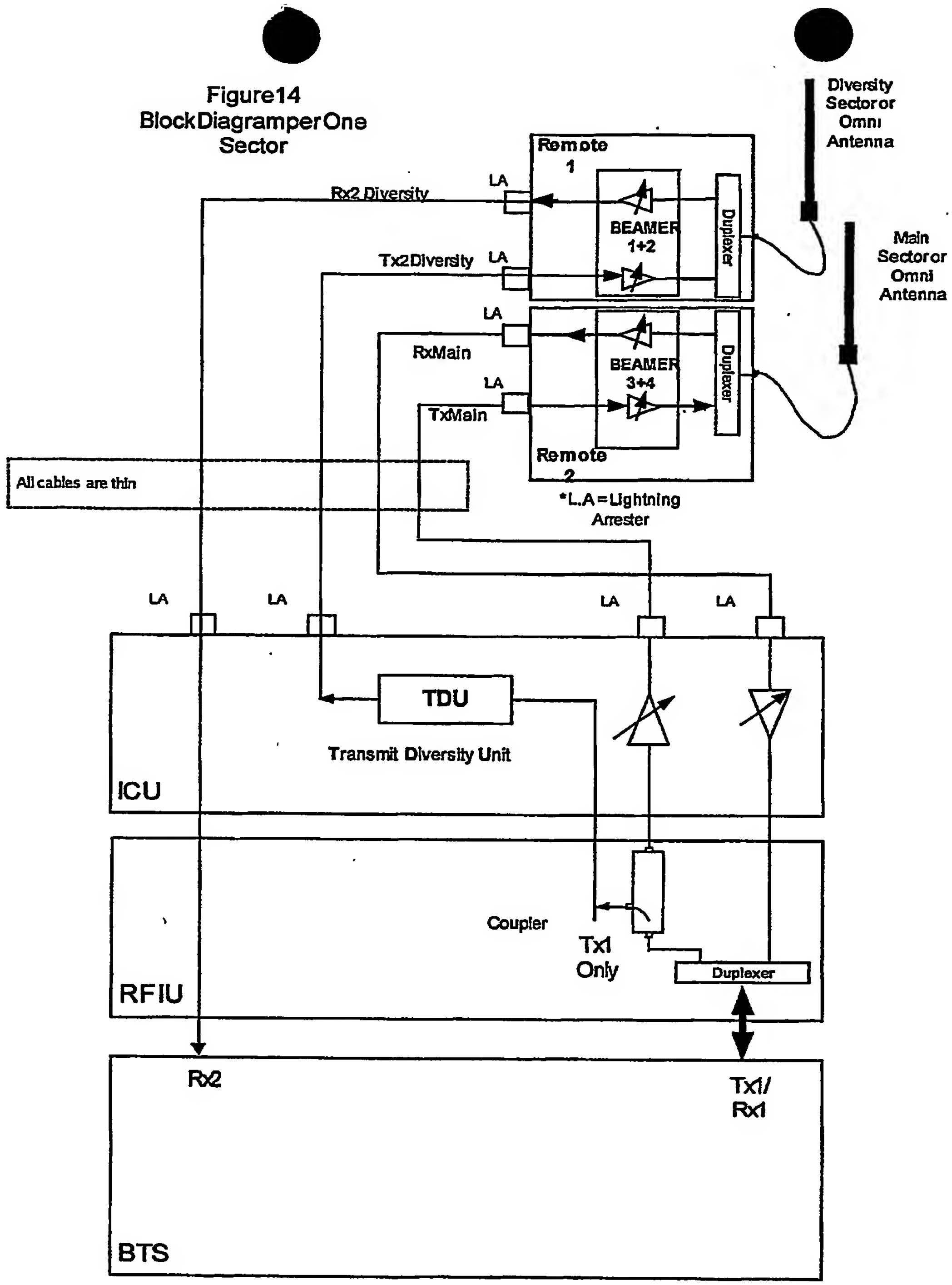


Figure15
Block Diagram per One Sector